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ABSTRACT

In an effort to help determine the processes underlying the acquisition of various mathematical skills, this study examines some of the effects of computer based instruction on achievement in mathematics. The research reported in this document is based on the following questions: (1) what is the relationship between such attributes as sex, ethnicity, socioeconomic status, ability and mathematics achievement in computer based educational programs? (2) are there demonstrable differences in mathematics gain that are related to various content standards? and (3) how do such instructional factors as time on task and instructional management impact on achievement? These questions are addressed by looking at the performance of samples of elementary and secondary students enrolled in a drill and practice computer assisted instruction program. Among the findings of the research conducted with the elementary students were: (1) at the primary level (grades 2 and 3), students of higher ability made greater gains on the computer program; (2) there were no significant differences in performance at the intermediate level (grades 4, 5, 6); and (3) at the advanced level (grades 7 and 8) the students of lower ability had greater gains. Findings at the secondary level suggest that computer assisted instruction maximized individualized instruction and had beneficial learning effects for all ability level students. References are included. (TW)

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THE IMPACT OF COMPUTER ASSISTED INSTRUCTION ON MATHEMATICS LEARNING GAINS OF ELEMENTARY & SECONDARY STUDENTS

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Section I

Introduction and Related Literature

A. INTRODUCTION

The concern for competency in mathematics has led mathematics educators in search of trying to unravel the processes underlying the acquisition of various mathematical skills. The consensus which has emerged from these efforts underscores the saliency of four sets of factors: (1) subject variables or the characteristics of the learner; (2) task variables, i.e. the mathematics content problems themselves; (3) process variables - i.e. the cognitive mechanisms students use to solve mathematical problems; and (4) instructional or environmental factors (Lester, 1980).

Of these sets of variables, the greatest attention has focused on instructional or environmental factors. Certainly one has seen within the past twenty years attempts to juxtapose more novel techniques to the conventional strategies of teaching mathematics. In the forefront of these are computer based educational programs.

Increasingly, more and more school districts are opting for this type of instructional strategy in their attempts to improve achievement in the basic skills. Early evaluations of the effectiveness of computer based educational programs have been overwhelmingly positive. However, the nature of the published research has been limited by their minimal attempts to integrate previous findings on mathematics achievement into design paradigms aimed at understanding achievement under computer based instruction.

The typical design paradigm is of an experimental nature in which the performances of students receiving computer assisted instruction are compared to some control group (see Kulik et al 1983 review for example; also Hartley, 1978). Thus, questions regarding the impact of subject and task variables on achievement in computer based educational programs are left relatively unanalyzed.

These questions are, however, quite salient for a number of reasons. First, as a particular mode of instructional strategy, computer assisted instruction may be better suited for the cognitive styles of some students, while not for others. Second, providing information on the relationship between various pertinent variables and mathematics achievement on the computer gives both teachers and administrators useful information with which to plan maximum utilization of the computer. Thus, for example, if particular ability level students tend to derive significantly greater gains on the computer than other ability groups, one might wish to target this group of students for CAI instruction.

Third, information regarding student performance on the mathematical content (task) strands can be very instrumental in helping teachers to more effectively manage learning on the computer. It may be that for content strands on which students are experiencing difficulties in mastery on the computer, teachers would need to reinforce these skills within the classroom lesson.

In approaching this topic, this study took as a conceptual point of departure Lester's (1980) propositions that subject, ability, task, environmental, and process variables impinge on mathematical achievement. These relationships are diagrammed in Figure 1. The underlying premise is that achievement in mathematics can be schematically expressed as a function of the student's social characteristics and ability, instructional

factors such as time on task, the nature of the task, i.e. lower order or higher order mathematical tasks, and processing variables, which include such things as reasoning and the application of various mathematical algorithms etc.

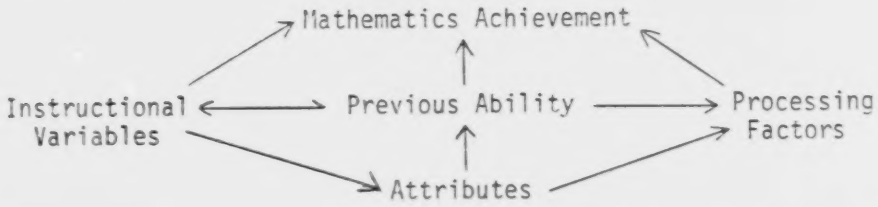


Figure 1. Model of Mathematics Achievement

The Model above serves as a basis for the following questions:

Research Questions

1. What is the relationship between such attributes as sex, ethnicity, socioeconomic status, ability and mathematics achievement in computer based educational programs?

2. Are there demonstrable differences in mathematics gains that are related to the various content strands?

3. How do such instructional factors as time on task and instructional management impact on achievement?

These questions are answered by looking at the performance of elementary and secondary students enrolled in a drill and practice computer assisted instruction program. Because of the lack of comparability of the mathematic courses in which they were enrolled the analysis was conducted separately for the elementary and secondary schools.

The paper is schematically divided into the following sections. A synopsis of the available research evidence on computer assisted instructions as well as the general findings on mathematics achievement is presented in the second part of this section. A discussion of the findings pertaining to the relationships among the variables at the elementary level is presented in Section II, while section III is devoted to an analysis of the data from the secondary sample.

B. RELATED LITERATURE

The trend towards adopting computer based instruction is rooted both in theoretical as well as programmatic educational foundations. Much of our theoretical insights into the cognitive development of mathematical skills are based on psychological theories, for example, the structuralism of Piaget (1952) and Bruner (1960). Skinner's (1968) notion of operant conditioning, however, has been instrumental in shoring up arguments in favor of programmed learning and computer assisted instruction (Gibb & Lamb, 1975).

Additionally, findings reported by Rosenshine and Furst (1971), as well as Gordon (1971), which highlight the significance of the inclusion in the instructional environment of such attributes as (1) frequent feedback to learners, (2) tutorial relationships, (3) individual pacing, (4) individual programing, (5) clarity of presentation, (6) motivational factors, and (7) task oriented instruction for improving learning, have strengthened the case in favor of computer based education.

Proponents of computer based education have forcibly argued that the computer has the unique ability to incorporate the above attributes. Given its adaptive instructional capabilities, the computer displays versatility in on-line drill and practice, individualized instructional prescriptions, immediate feedback, diagnosis of individual errors and assignment of remediation. In addition to which, the computer has been found to have a positive facilitating effect on student attitude, motivation, and interest in mathematics (Overton, 1981).

From a pragmatic educational viewpoint, computer based education has the advantages of (1) allowing the faculty to teach higher level specialized courses, (2) providing additional class-time for higher level

instruction by removing basic skill development from the classroom and assigning it to the computer; and (3) providing opportunities for the creative development of innovative curriculum materials (Hall, 1975).

Computer based programs have been extensively used in mathematics instruction. The most widely adopted modes of instructional strategies are drill and practice, and tutorial (Overton, 1981). Drill and practice as an instructional strategy under computer assisted instruction involves student use of the computer to master concepts and techniques that have been learned from other sources. On the other hand, the tutorial mode of instruction involves the presentation of new materials directly from the computer. Students' learning activities are monitored, and, as they progress, more complex tasks are presented.

Evaluation of achievement under both types of instructional strategies seems to indicate that CAI is most effective when used as a drill and practice instructional tool rather than as a tutor. Studies by Cranford (1976), Romero (1979), and Modisett (1980) have unearthed significant positive effects on mathematics achievement for students enrolled in computer drill and practice programs.

Romero (1979), for example, in a study of first and second quartile middle school students, compared regular math instruction with the drill and practice format. Significant differences in achievement between the two groups were found. Students taking drill and practice on the computer performed significantly better on the Metropolitan Achievement Test than students receiving regular math instruction only.

This trend was substantiated by Modisett's (1980) findings on low achieving students in grades 9, 10, and 11. Compared to the workbook,

Modisett found computer assisted instruction as a form of remediation to be far superior. Students belonging to the CAI group showed an average growth in computational skills of 10.5 months of regular schooling as compared to 4.7 months for the workbook students.

The research evidence on the use of the computer as a tutor has been less definitive. Pachter (1979), for example, noted that students who were taught factoring on the computer were more successful in mastering these skills than students taught by conventional methods. However, Eschenburg (1978) obtained mixed achievement results in a study that examined low achieving ninth, tenth, and twelfth grade students using computer supported instruction.

A global picture of the accumulated research evidence on computer based education is provided by the Meta analyses conducted by Kulik et al (1983) and Hartley (1971). The findings, as reported by these authors, for classificatory reasons can be grouped into three areas (1) those related to comparative evidence on the impact of CAI instruction versus non-CAI instruction; (2) those pertaining to grade level effects i.e. elementary versus secondary and (3) those related to the differential impact of CAI on students with different ability levels and socioeconomic backgrounds.

The evidence, as cited in these meta analyses, has been overwhelmingly positive in favor of computer assisted instruction versus regular instruction only. Lysiak et al (1976) looked at the effect of CAI on math and reading achievement for qualifying Chapter I students. Their study showed that students made at least a monthly gain, per month of instruction on the computer curricular. Middle school CAI students made significantly higher standardized test gains than did non-CAI students. Elementary mathematics gains also generally favored CAI students.

In her meta analysis of findings on computer based instruction in mathematics education in elementary and secondary schools, Hartley (1971) reported that the average effect of computer based instruction was to raise student achievement by .41 standard deviations. Elementary students did better with computer based teaching than did secondary students. At the elementary level computer based instruction raised examination scores by .4 standard deviations while at the secondary level, scores were raised by .3 standard deviations.

Kulik et al (1983) noted in their review of the evidence that the effects of computer based teaching appeared to be positive for low aptitude and disadvantaged students. For example, in citing the results of Jamison's, Suppe's and Well's (1974) study, Kulik et al reported that the study found at the elementary levels that computer based teaching, when used as a supplement, had improved achievement scores, especially for disadvantaged students. This finding was supported by Burns and Bozeman (1981) analysis of 40 studies of mathematics achievement which revealed that CAI drill and practice was more beneficial for both disadvantaged and high ability students than for average ability students.

In the more general field of mathematics education a number of research data have burgeoned on such student attribute variables as sex and socioeconomic background. Important empirical strides have also been made in understanding the relative performances of students on the various mathematical content strands.

A number of studies have looked at sex-related differences in mathematics achievement (Stafford, 1972; Sherman, 1977; Fennema, 1974; Fennema and Sherman, 1977; Aiken, 1971, Callahan and Glennon, 1975). Fennema (1974), in a review of 38 studies which looked at sex related differences

and mathematics achievement, reported finding no significant differences between boys or girls mathematics achievement before or during early elementary years. Apparent differences in the upper elementary and high school years were between levels of cognitive tasks. Boys were favored when the tasks were at higher cognitive levels, and girls were favored when the tasks were at lower cognitive levels.

The Coleman report (1966) did much in spearheading a concern with looking at the relationship between socioeconomic background and mathematics achievement. The research evidence garnered seemed to indicate that much of the variance in mathematics achievement appears to be accounted for by socioeconomic factors. Students with high socioeconomic backgrounds tend to achieve better than students from low socioeconomic levels.

The research appertaining to students' performances on the task variables in mathematics suggest that while computational achievement with whole numbers is high, achievement on the content strands of fractions and decimals appears to be problematic (NAEP report 1979). The most problematic mathematical task, however, is problem solving, where test scores tend to be low and where students tend to experience difficulty in applying their computational skills.

In summary, one may state that the research evidence reviewed has been fairly supportive as to the positive impact of computer based instruction in raising mathematics test scores, and in particular, when it is used as a drill and practice instructional tool.

SECTION II

Elementary Schools

A. METHODOLOGY

Eight elementary schools offer CAI instruction. There is much variation from one school to another in that the grade levels using CAI are different, students' ability levels vary, in some schools an aide is assigned to the instruction task, while in other schools a certified teacher works with the children. Some children receive Chapter I services in addition to CAI instruction; others do not. The software programs used are not the same everywhere. All schools do use the Math 1-6 program, but only a few use the Problem Solving program.

The Math 1-6 program is a highly individualized program, tailoring lessons to each student's level, and covering all topics in elementary school mathematics except geometry and word problems. The Problem Solving program is also individualized, and is designed to give students practice in solving word problems.

As indicated in the Introduction, the interest of this study is to ascertain whether the instructional factors, as well as subject factors, such as sex, ethnicity, and ability level are related to CAI mathematics achievement. Further, it is our intention to examine the content strands within the math programs in terms of their level of difficulty as experienced by Newark elementary students. The specific questions which are addressed here are:

1. Are there any variations in total gain scores for the Math 1-6 program by:

   a) ability level
   b) grade level
   c) ethnicity
   d) sex
   e) nature of instruction (teacher or aide)
   f) other services or not (Chapter I or SCE)

2. Are there any variations in the total gain scores for the Problem Solving program by the above six variables?

3. Within the Math 1-6 program, what are the differences in the level of difficulty of the different content strands (e.g. vertical addition, vertical subtraction, equations, etc.) as experienced by Newark elementary students?

4. Are there growth differences by ability level, sex or grade level in the more difficult strands, as well as in the less difficult strands?

A sample of 152 students was drawn. Within the Newark school system, students in grade levels two through eight received CAI instruction. All of the students receiving instruction in the 2nd and 3rd grades who had complete data were included. Those without CTBS scores or those who had not yet been appropriately placed in the Math 1-6 program as of November were excluded. A sample was drawn of 4th, 5th, 6th, and 8th graders who had complete data. All four seventh graders who fit our criteria were included. Table 1 shows the breakdown of the sample by grade level, as well as by sex, ethnicity, whether instructed by aide or teacher, and whether receiving Chapter I/SCE services or not.

In later analyses grades 2 and 3 were combined to form a primary grade level, grades 4, 5, and 6 were combined to form an intermediate level, and grades 7 and 8 were combined to form an advanced level.

Table I

Grade Level, Sex, Ethnic and Instructional
Characteristics of Elementary Student Sample

Grade Level	# of Students	Sex	# of Students	Ethnicity	# of Students	Instruction	# of Students	Receiving Other Services	# of Student
2	28	F	81	Spanish	27	Aide	119	Yes	49
3	30	M	71	Non-Spanish	125	Teacher	33	No	103
4	15								
5	18								
6	39								
7	4								
8	18								

All of the students in the sample were instructed with the use of the Math 1-6 program. Thirty eight students were also using the Problem Solving program. Performance was measured by growth in mathematics achievement from the student's initial placement on the computer until the end of January, 1984. Such growth is generated by computer in the form of a gain score.

As one might suspect, there is a very high correlation between time on task and performance. The relationship between the total amount of time spent on the Math 1-6 program and the total Math 1-6 gain score (indicating the total amount of growth in mathematics achievement) is .70. The correlation between the time spent on the Problem Solving program and the total problem solving gain score is .93. Because of these high correlations, relative gain scores were calculated for each student by dividing the total gain into the total time spent. This solved two problems. One, it controlled for the time-on-task variable, and two, it created an interval scale for performance. (The gain scores are given in terms of grade equivalents, which are not interval scales.) Thus, there were two relative gain scores, math 1-6 gain score and problem solving gain score, which were used as the measures of student performance in subsequent analyses.

A student's ability level was determined by his/her total math score on the Comprehensive Test of Basic Skills (CTBS) administered district-wide in May 1983. Three ability levels were created. Students in the lowest group had normal curve equivalent (NCE) scores of 40 lower. (The cut-off scores for inclusion in the Chapter I program were 42 for grades 2, 7, and 8, 43.6 for grades 4, 5, and 6, and 28 for grade 3.) The middle ability level scored between 41 and 60, and the top ability group scored 61 or more. The number of students in each group was 53, 47 and 50 respectively.

B. RESULTS: SUBJECT AND INSTRUCTIONAL FACTORS

A correlation matrix of all variables is presented in Table II. There is no relationship between the gain scores in Problem Solving and those in Math 1-6 among those students who are being instructed through the use of both programs. As far as the zero order relationships between math performance and the other variables in the study are concerned, there are no significant correlations between achievement in the Math 1-6 program and any other variable, whereas Problem Solving growth is associated with sex, ethnicity and instruction. Boys have higher scores than girls, those of Spanish background have higher scores than others, and those receiving instruction from teachers have higher gains than those receiving instruction from computer aides. An examination of the intercorrelations among the independent variables indicates that there is a very high relationship between ethnicity and instruction (.72), such that those of Spanish background are receiving instruction from a teacher and others are receiving instruction from an aide. Because of this high association and because the number of students of Spanish background is small, as is the number of students receiving help from a teacher, it is impossible in this analysis to ascertain the independent effects of each of these variables.

Sex

Sex is not related to any of the other variables, which means that the difference here is probably real. Boys perform better in the program requiring higher cognitive skills. Although sex and Math 1-6 gain scores were not related in the case of the entire sample, there was some question as to whether there might be variations in the relationships within grade levels. Table III presents the results of t-tests, comparing mean Math 1-6

Table II
Correlation Matrix of all Variables

	1	2	3	4	5	6	7	8
1. Grade Level	1.00							
2. Ability	-.35	1.00						
3. Sex[a]	.03	.05	1.00					
4. Ethnicity[b]	-.11	.13*	-.05	1.00				
5. Instruction[c]	.14*	1.32**	-.01	-.72**	1.00			
6. Other Services[d]	-.41**	.58**	.08	.38**	-.59**	1.00		
7. Math 6 Gain	.02	.12	-.09	.12	-.03	.06	1.00	
8. Problem Solving Gain[e]	-.02	-.01	.31*	-.31*	.29*	.06	-.09	1.00

*p < .05
**p < .001

[a] female = 1, male = 2
[b] Spanish = 1, other = 2
[c] Aide = 1, Teacher = 2
[d] Other Services = 1, No other services = 2
[e] Number of students using problem solving program is 38

Table III

Results of t-tests
Comparing Male and Female Math 1-6 Gain
Scores within Three Grade Levels

	# of Cases	Mean Score	Standard Deviation	F Value	2-tail Prob.	T Value	2-tail Prob.
Level 1 (Primary)							
Females	33	.17	.20	2.95	.088	.76	.45
Males	25	.14	.12				
Level 2 (Intermediate)							
Females	36	.15	.12	2.69	.005	1.15	.25
Males	34	.12	.07				
Level 3 (advanced)							
Females	11	.15	.07	1.38	.62	.44	.66
Males	11	.14	.08				

gain scores of boys and girls within each of the three grade levels. The t values were not significant at any grade level, indicating that there were no sex differences. One might note, however, that in all cases the girls' scores were slightly higher than the boys. Further, the standard deviations and F values show that there was much greater variation in the scores of girls than of boys at the primary and intermediate levels. Girls did both better and worse than boys. Although the standard deviations decreased from primary to intermediate levels for boys, the decrease was greater for girls and continued through the advanced level.

Ability Level, Grade Level, and Sex

The relationship between ability level and grade level, showing that higher grades have greater proportions of lower ability children, may be confounding the relationships of each of these variables with performance. The relationship between ability level and sex for the entire sample was nil, but within grade levels the relationships varied. At the primary grade level, girls' ability level was higher (-.18). At the intermediate and advanced levels, boys' ability levels were higher (.21 and .28 respectively). The correlations were not high, but each were each greater than the .05 correlation shown in Table II.

The independent effects of sex and ability level on performance were assessed within grade levels through regression analysis. Table IV gives the Beta weights for each variable. Interesting differences occur. At the primary level, higher ability children do better and there are no sex differences. At the intermediate level, although no relationships were significant, the relationship between ability level and performance was positive, i.e., higher ability children had higher gain scores, and girls

Table IV

Regression of Math 1-6 Gain Scores on
Sex and Ability within Grade Levels

	Beta Weights	F Value	N	r^2	F
Primary					
Sex	-.03	.07	58	.11	3.35**
Ability	.32	6.14***			
Intermediate					
Sex	-.17	1.95	70	.05	1.82
Ability	.19	2.46			
Advanced					
Sex	.02	.01	22	.19	2.28
Ability	-.44	4.32*			

*p < .10
**p < .05
***p < .01

scored slightly higher than boys. At the advanced level, the relationship between ability and performance reverses itself. Lower ability children did better. There were no sex differences.

Other Services

In the correlation matrix (Table II) there were significant associations between other services and grade level, ability level, ethnicity and instruction. In two of the schools, the CAI program is part of the Chapter I program and is supervised by a teacher instead of an aide. Both of these schools have large Spanish populations. Grades 2 and 3 are not offered CAI instruction in these schools. Therefore, in order to assess whether CAI students receiving additional Chapter I or SCE assistance perform differently from those who do not, students from only one school were selected. All students in this school are non-Spanish. All CAI instruction is given by a computer aide, and is offered to 6th, 7th, and 8th grade students only. Table V presents the results of the t-test. There is virtually no difference between the two groups. The additional assistance does not seem to have any effect on CAI performance.

Table V

Results of t-test Comparing Mean
Math 1-6 Gain Scores of CAI Students
Receiving Chapter I/SCE Assistance with Those Who Do Not

	# of Cases	Mean Score	Standard Deviation	F Value	2-tail Prob.	T Value	2-tail Prob.
CAI Students Receiving Chapter I/SCE	14	.136	.067	1.58	.430	.02	.986
CAI Students not Receiving Chapter I/SCE	12	.136	.085				

C. RESULTS: MATH 1-6 CONTENT STRANDS

The Math 1-6 program has 14 content strands. Each strand is a series of exercises on the same concept. (see Table VI for a list of the strands and the grade levels that each covers.) The exercises in each strand are grouped into "equivalence classes", each of which is a set of homogeneous exercises. The equivalence classes are arranged in ascending levels of difficulty. When a student masters one class, he/she moves up to the next class. Rates of movement may be different for the different strands - depending on the degree of difficulty of exercises for that particular student.

We wished to ascertain the relative difficulty of the different strands for Newark students. Different strands cover different grade levels, as can be seen in Table VI. Number concepts, equations and measurement cover a wider range of grade levels than other strands. Number concepts and horizontal subtraction begin at grade 1. Fractions and decimals begin at grade 4. The level of difficulty of a strand was assessed by looking at the grade levels at which the strand began, the relative starting points of Newark students in each strand, and the relative gains made in each strand. Here, the gains were determined by the growth which was made in each strand between November, 1983 and the end of January, 1984. In order to determine the relative starting points and the relative gains, the Friedman two-way analysis of variance test, which is a test of mean rankings, was used to see if there were significant differences in rankings among the different strands. A relatively low starting point and a relatively low gain score were indicators of greater difficulty, other things being similar.

Table VI

Strands and Grade Levels
for Math 1-6 CAI Program

Strand	Name	Grade Level
1	Number Concepts	1.0-7.9
2	Horizontal Addition	1.0-4.4
3	Horizontal Subtraction	1.6-4.4
4	Vertical Addition	1.5-5.8
5	Vertical Subtraction	1.6-5.8
6	Equations	2.0-7.9
7	Measurement	2.0-7.8
8	Horizontal Multiplication	2.6-5.8
9	Laws of Arithmetic	3.0-6.8
10	Vertical Multiplication	3.5-7.8
11	Division	3.5-7.8
12	Fractions	4.0-7.9
13	Decimals	4.0-7.9
14	Negative Numbers	6.0-7.9

Primary Level

Students in grades 2 and 3 were being drilled, for the most part, in the first 5 strands. The strands are similar in the sense that the formal starting level for each is in grade 1 and each extends beyond grade 3 (see Table VI). The mean ranks for the actual beginning scores of Newark's primary level students and the mean ranks for their growth scores are presented in Table VII. Horizontal addition is the easiest strand and vertical addition the most difficult of these 5 strands for these students. The starting point is higher and the gains greater in the case of horizontal addition. The exact opposite is true in the case of vertical addition. The differences among the strands were not as great for gain scores as for starting scores. In the latter case, there were substantial intervals between the mean rankings. Regarding gain scores, horizontal subtraction, number concepts and vertical subtraction were similar.

Table VII

Mean Ranks of First Five Strands of Math 1-6
Program: Primary Level Students

Starting Level: Mean Ranks		Gain Scores: Mean Ranks	
Vertical Addition	2.48	Vertical Addition	2.46
Vertical Subtraction	2.79	Horizontal Subtraction	3.00
Number Concepts	2.93	Number Concepts	3.10
Horizontal Subtraction	3.29	Vertical Subtraction	3.13
Horizontal Addition	3.51	Horizontal Addition	3.31

$X^2 = 14.55$
$p < .01$

$X^2 = 8.83$
$p < .10$

The next step was to look at the relationship between ability and gain scores for each of these strands. The correlation between ability and gain scores in horizontal addition is .37, and between ability and vertical addition is .42. Higher ability students do better in both cases, but especially in the more difficult skill area.

There were no sex differences in either case.

Intermediate/Advanced Levels

Eighty seven students (grades 4-8) were working in the first 8 of the 14 strands. Horizontal addition and subtraction "topped out" at grade level 4.4, meaning that when all items within the strand had been mastered, the student was performing at a 4.4 grade level. Because a number of students did "top out", making it impossible to adequately measure gain scores in these two strands, the two were not included in further analysis. Table VIII presents the mean rankings for starting scores and for gain scores for the remaining six strands. Both equations and measurement had relatively low rankings in start scores and gain scores, indicating greater

Table VIII

Mean Ranks of Start Scores and Gain Scores
in 6 Math 1-6 Strands, N=87, 1=Low, 6=High

Start Scores: Mean Ranks		Gain Scores: Mean Ranks	
Vertical Addition	3.69	Equations	4.12
Equations	3.79	Vertical Subtraction	4.44
Measurement	4.43	Measurement	4.81
Vertical Subtraction	5.09	Horizontal Multiplication	5.05
Number Concepts	5.16	Vertical Addition	5.11
Horizontal Multiplication	5.93	Number Concepts	5.17

$X^2 = 81.9$
$p < .001$

$X^2 = 40.15$
$p < .001$

difficulty in these skills. Number concepts and horizontal multiplication had higher rankings, indicating that these were easier skills. Vertical addition operated in opposite ways. It was lowest to begin with, but next to the highest in gain score.

Equations and measurement gain scores were combined to form a "high skill" performance dimension, and number concepts and horizontal multiplication were combined to form a "low skill" dimension. They were each regressed on sex and ability. The results are shown in Table IX. None of the relationships were significant. There were no differences in terms of ability level regarding performance on either the high skill or low skill strands. Neither were there significant sex differences. The largest correlation was -.19, indicating that girls may have a slight edge on the high skill strands.

Table IX

Regression of High Skill and Low Skill Gain Scores on Sex and Ability, Grades 4, 5, 6

	Beta Weights	F Value	r2	F
High Skill				
Sex	-.19	3.00	.04	1.70
Ability	-.02	.03		
Low Skill				
Sex	.00	.00	.01	.28
Ability	-.08	.50		

There were 26 sixth to eighth graders who were working in 13 of the 14 strands (only 2 students were working in all 14 strands). According to our criteria of difficulty, fractions, decimals, and equations are considered most difficult and number concepts, laws of arithmatic and division are the least difficult. (See Table X). Difficulty, as experienced by Newark students, is not directly comparable to the ordering of the strands (Table IV). Vertical multiplication, division, fractions and decimals are all skills which begin at grade level 3.5 or 4.0. Yet division is considered one of the least difficult strands by Newark students. It is possible that division is being emphasized in the classroom, whereas equations, fractions, and decimals are not.

Table X

Mean Ranks of Start Scores and Gain Scores
in 11 Math 1-6 Strands: N=26

Start Scores: Mean Ranks		Gain Scores: Mean Ranks	
Fractions	5.86	Decimals	5.65
Decimals	5.86	Horizontal Multiplication	6.15
Equations	5.95	Fractions	6.39
Vertical Multiplication	6.84	Equations	6.65
Vertical Addition	6.91	Vertical Addition	6.69
Horizontal Multiplication	7.38	Vertical Subtraction	6.73
Vertical Subtraction	7.44	Measurement	7.77
Measurement	8.09	Vertical Multiplication	8.44
Laws of Arithmetic	8.45	Number Concepts	8.60
Number Concepts	9.67	Laws of Arithmetic	8.76
Division	11.86	Division	11.48

$X^2 = 137.3$
$p < .001$

$X^2 = 105.29$
$p < .001$

Fraction, decimal and equation gain scores were combined to form a "high skill" dimension, and number concepts, laws of arithmetic and division gain scores were combined to form a "low skill" dimension. Each of these was regressed on sex and ability (Table XI). The significant relationship was between ability and low skill gains. Those students of lower ability gained significantly more on the low skill strands than did those of higher ability.

Table XI

Regression of High Skill and Low Skill Gain Scores on Sex and Ability; N=26; Grades 6-7-8

	Beta Weights	F Value	r^2	F
High Skill				
Sex	-.08	.13	.11	1.35
Ability	-.27	1.40		
Low Skill				
Sex	.13	.59	.50	11.4*
Ability	-.77	19.56*		

*$p < .01$

D. SUMMARY AND DISCUSSION

The questions addressed at the elementary level were essentially three-fold. How are subject factors and instructional factors related to CAI math performance? Are some content strands within the Math 1-6 program more difficult for Newark students than others? Does performance on the more difficult and less difficult strands vary by subject factors? By answering these questions, we hope that we can provide information that will be useful to those making decisions regarding the uses of computer assisted instruction.

Subject and Instructional Factors

At the primary level (grades 2 and 3), students of higher ability - as determined by total math scores on CTBS - made greater gains on the Math 1-6 program, and particularly on the more difficult content strands. At the intermediate level (grades 4, 5, 6) there were no significant differences in performance by ability, and at the advanced level (grades 7 and 8), the students of lower ability had greater gains, especially on the less difficult content strands. In our sample the ability level of the younger age group is higher than that of the older groups (mean ability level = 2.3, 1.9 and 1.5 respectively for the 3 grade level groups). The fact that within the younger group, the higher ability children do better seems to indicate that there is some minimum level of maturity necessary in order for children to benefit from CAI instruction. Indeed, 2nd graders as a group have the lowest gains of any grade level. While there are some second grade students who do progress in the math program, the majority make minimal gains. It would seem, then, that second graders are probably too young to derive much benefit from CAI instruction. Given the fact that higher ability 3rd grade children benefit and that, as one moves up the

grade levels, lower ability children gain more, computer drill and practice is most helpful to those who are "ahead" when they are beginning learners of certain math skills and those who are "behind" in later grades.

The sex difference which existed indicates that boys do better than girls on the Problem Solving program, confirming the research findings mentioned in Section I that "boys were favored when the tasks were at higher cognitive levels". The converse, that "girls were favored when the tasks were at lower cognitive levels" is not born out here. It is true that the direction of association for most of the relationships between sex and Math 1-6 gains was in favor of the girls (see Tables IV and IX) but none of the relationships was significant. The fact that there was greater variation in the girls scores at the primary and intermediate grade levels and that the tilt in favor of girls at the intermediate level occurred for the high skill strands and not the low skill ones makes one wonder about socialization practices and gender. Perhaps if girls succeed equal to, if not better than, boys on the computer (which does not treat different sexes differently), that will carry over into self images and teacher images regarding sex and mathematics.

No conclusions could be drawn regarding the effects of ethnicity nor of instruction because the two were highly linked. Students of Spanish background were taught by a teacher instead of an aide. This group had higher scores on the Problem Solving program.

Students receiving Chapter I or SCE assistance in addition to CAI performed no differently than students not receiving such assistance. The effects of CAI, then, do not seem to be influenced by what else is going on in the child's life at school.

Math 1-6 Strands

Different mathematics skills are introduced at different grade levels - both on the CAI program and in textbooks - as there is a sequential order in which the different skills are learned. For example, one must know addition and subtraction before one can learn multiplication. Regardless of when a particular skill is introduced, however, there are greater and lesser degrees of complexity - so that one may still be learning addition skills in the 4th grade, even though addition began in grade one.

There are a total of 14 math strands or skills in the Math 1-6 CAI program. For the most part, the difficulty of the skills, as experienced by Newark students, coincides with the ordering by which the skills are introduced, i.e. the more difficult skills are those introduced at a later point in time. There are, however, some exceptions. Division is not introduced until grade level 3.5. Equations and measurement are introduced at grade level 2.0. In terms of difficulty, equations and measurement are considered by Newark students to be considerably more difficult than division. This suggests that there is some disparity between the CAI curriculum and the classroom curriculum in that more classroom time is spent on division than on equations or on measurement. CAI success in these areas would probably be heightened if more classroom time were spent.

Fractions and decimals are introduced later and are considered to be more difficult. There is evidence elsewhere that "math anxiety" begins at this point in the math curriculum (Kogelman and Warren, 1979; Tobias, 1978). It would seem that more time is needed in these areas - not only to enhance these skills, but also to overcome whatever psychological blocks may be contributing to the lack of skill development.

For most of the students in the sample, there were no significant sex or ability differences in "high skill" achievement nor in "low skill" achievement. The exception occurs in the case of upper grade level students (6, 7, 8) who are working in 13 of the 14 skill areas. The lower ability students performed better in the "low skill" area than did higher ability students. This reinforces a point made earlier in this discussion - that for older students, the CAI drill and practice program is very beneficial in helping them to master skills that should have been learned at an earlier point in time, i.e. it is a good remedial tool.

An observation regarding the administration of the CAI program is pertinent to this discussion. In many schools there does not seem to be much coordination of activity between CAI instruction and classroom instruction. The above analysis would suggest that CAI instruction is beneficial for less complex skills, thereby freeing teachers for the instruction of the complex skills.

Section III

The Impact of Computer-Assisted Instruction on the Mathematical Achievement of High School Students

A. INTRODUCTION

The pedagogical benefits of computer assisted instruction as an effective intervention strategy for low achieving mathematical students at the secondary level have been well documented by various researchers. Consistently, it has been shown that students receiving computer instruction, particularly in a drill and practice format, tend to demonstrate significantly better learning gains than students without this assistance.

Indeed, it has been argued that computer assisted instruction is aptly suited for aiding the development of mathematics skills, since mathematics is a hierarchically ordered field in which each skill builds on a foundation provided by lower level skills. While, therefore, there can be no questioning of the beneficial instructional effects of CAI, information pertinent to understanding the nexuses of variables likely to influence mathematics achievement on the computer remains scant.

The conceptual model introduced in Section I, which postulated a set of relationships between subject, task, and instructional variables and mathematics achievement, serves as a reference point for examining these relationships more from a relational than causal perspective among the high school sample. In recaptulating the premises on which the model rests the following propositions may be stated. Mathematical Achievement is a function of the interrelationship between the learner's characteristics

i.e. his sex, socioeconomic background and previous ability, instructional factors, processing modes and complexity of the mathematical task.

In applying this conceptual scheme to explaining mathematics achievement in computer based educational programs one may ask whether, given the individualized nature of instruction on the computer, one is likely to find the same pattern of relationships. Arguments in favor of the relevance of the model derive from two sources. First, the available literature and evaluation data have been fairly supportive of ability and social background differences in mathematical gains on the computer. Thus, even though the various software computer educational programs do take into account differences in learning aptitude among students, persistent relationships between learner characteristics and mathematical gains do occur. The second and more substantive point is that the computer is an alternative instructional method of presenting and teaching mathematics. Consequently, one can expect that its impact on learning will be somewhat tempered by its degree of congruency with the processing or cognitive styles of the learner.

Research on individualized instruction has indicated that, while some learners do obtain clear learning gains, others experience little or negative learning effects from individualized systems (Glass, 1976; Kulik, 1975). These effects appear to be related to the cognitive style of the students. Thus, some students learn more effectively in a group setting, while others do better in individualized systems.

Having established the relevance of the model, the following research questions generated from the model are studied:

a. What is the relationship between learner characteristics, previous ability and mathematics achievement on the computer?

b. How does computer assisted instruction impact on the development of simple and complex computational skills?

c. How do such instructional factors as time on task, and the instructional management of computer assisted instruction impact on learning gains?

B. METHODOLOGY

The sample consisted of 96 students from grades 9, 10, 11, and 12. These students were receiving computer assisted instruction as a supplement to their regular instruction. Most of the students, based on their standardized achievement test results on the Comprehensive Test of Basic Skills, qualify and in some cases are receiving either Chapter I remedial services, or State Compensatory Education services.

A profile of the sample in terms of demographic attributes indicates that 48 were female, 48 were male. There were sixty three students with English spelling surnames, and 33 with Spanish spelling surnames. Thirty four of the students in the sample attended school in a relatively higher SES neighborhood, and 62 attended schools in poorer neighborhoods.

All students in the sample were enrolled in the course Adult Arithmetic Skills. This course builds proficiency in basic computational skills which students need for both practical and educational reasons. It is a highly individualized course moving students to appropriate levels of difficulty according to a diagnosis of their individual weaknesses and strengths.

The curriculum covers eight mathematical content strands: addition, subtraction, multiplication, division, equations, fractions, measurement, and decimals, with 36 levels of difficulty. However, within each strand there are different difficulty levels. Students work at a particular level of difficulty within a strand until they are answering most of the exercises correctly, then they are moved to the next level.

Operationalization of Variables: Mathematics achievement was operationalized by using the scores for each content strand and course average generated by the computer for the end of November and end of January. In the first set of data analysis learning gains were arrived at by taking the difference between the course averages for the end of November and end of January. The analysis of achievement on the content strands (see Section C) was approached from a different perspective.

Within each content strand, there are a number of items with different levels of difficulties. Thus, for example, on the addition strand there are 25 levels of difficulties and for subtraction 24. These levels of difficulties were treated as mastery objectives. The levels on which students were working for each of the individual strands were expressed as a percentage of the total number of objectives or levels for that strand. Thus for example, if a student on the subtraction strand was receiving items on level 12, this was translated to mean that he has mastered 50 percent of the objectives for this strand.

Students' previous mathematics ability was determined by using their performance on the two subtests of the Comprehensive test of Basic Skills: computation, and concepts and application. Whether students were classified as being mono or bicultural was based on their names. The socioecology of the school was arrived at by using information based on the number of families in the attendant neighborhood eligible to receive AFDC.

Statistical Analysis - Multiple regression procedures were used to estimate the relationships between student characteristics, previous mathematic achievement and learning gains demonstrated on the computer. Analysis of performances on the content strands relied on the application of nonparametric techniques. Wilcoxon matched sample tests were used to

determine whether there was any significant improvement on each of the content strands between the months of November and January. Spearman Rank Correlation (rho) was employed to measure the relationship between performance on the content strands and various learners' characteristics. Assessment of the impact of time on task and instructional management on mathematic achievement was arrived at through the use of linear flow graph techniques.

C. THE RELATIONSHIP BETWEEN LEARNER CHARACTERISTICS, PREVIOUS ABILITY AND MATHEMATICS ACHIEVEMENT ON THE COMPUTER

Bloom (1982), on the basis of the various empirical findings on school learning, developed a model in which any learning outcome could be explained by the interrelationship between students entry characteristics and the quality of instruction. The theoretical formulation on which the model is premised is that the history of a learner as subsumed by cognitive and affective entry behaviors is at the core of learning. This formulation is in agreement with Lester's (1980) findings regarding achievement in mathematics and, thus, provides us with a theoretical justification for exploring the relationships between learner characteristics, cognitive entry factors, and achievement.

Studies that have explicitly examined the relationships between learner characteristics, cognitive entry behaviors and mathematics achievement on the computer have yielded interesting findings. Previous mathematical ability and the social background of the student have been found to be consistently related to achievement in computer based educational programs. The direction of the relationships implied that lower mathematical

ability students as well as students from more disadvantaged social backgrounds were likely to derive greater learning gains than high ability students and students with better socioeconomic backgrounds.

These findings are opposite to those in the field of mathematical education focusing on conventional teaching strategies. The general trend that has burgeoned is for high ability students and higher SES students to be more proficient in mathematics.

In unraveling the relationship between these three sets of variables in this study the following analytic strategy was pursued. First, the relationship between students' characteristics, i.e. sex, ethnicity, and socioeconomic status and previous ability was established. Second, the extent to which these variables were related to learning gains on the computer was examined.

Our first line of analysis indicates that sex and the socioeconomic context of the school are factors that influenced the cognitive entry characteristics of students in the study on both indices of previous mathematical achievement (see Table XII). The direction of gender differences suggested that girls were less deficient in these skills than were boys. This finding was not surprising. Previous studies conducted on the remedial population in this school district have evinced similar patterns of results (Madhere and Walker, 1983). There were, however, no ethnic differences in the previous mathematical performance of students.

Of noteworthy interest was the significance of the socioeconomic context of the school as a predictor of student cognitive entry characteristics. The direction of association between the variables implied that students attending schools in poorer neighborhoods had higher mathematical ability levels. In ascertaining whether this finding was sample specific

Table XII

Zero Order Correlation Coefficients Representing the Relationship Between Sex, Ethnicity, Social Ecology of the School, Computational Achievement, Achievement in Concept and Application And Achievement on the Computer

	Computational Achievement	Achievement Concepts & Application	Achievement on the Computer	Sex	Ethnicity	Social Ecology of the School
Computational Achievement	1.00					
Achievement in Concepts & Applications	.60*	1.00				
Achievement on the Computer	.02	.06	1.00			
Sex	-.28*	-.28*	.03	1.00		
Ethnicity	-.01	.02	.27*	-.24	1.00	
Social Ecology of the School	.30*	.18*	.24*	.13	-.56*	1.00

*Significant at .01

or true of the population, we looked at the overall academic performance in mathematics for the schools in the sample, and found that in actuality the schools in the "better socioeconomic neighborhoods" had higher mathematical achievement levels. This led us to speculate that this finding was probably an artifact of the selection procedures used to place students on the computer. A cursory examination of the scores indicated that in schools located in poorer neighborhoods there were students receiving computer assisted instruction under the remedial component with scores higher than the State Minimum level of proficiency.

The relative predictive power of previous mathematical achievement and learner characteristics in explaining learning gains on the computer can be gleaned from Table XIII. A number of interesting findings are apparent. Students' cognitive entry characteristics as measured by previous mathematical performance in concept and application and computation are not significant in predicting the learning gains that students experience on the computer.

This clearly augurs well for computer assisted instruction. The implication being that instruction under this program is having beneficial learning effects for all ability level students. Thus, in maximizing individualized instruction, the computer is able to obviate any impact that previous ability might have had on mathematical learning outcomes.

Table XIII

Regression Results with Dependent Variables, Previous Achievement in Computation and Concepts and Application and Predictor Variables, Sex, Ethnicity and the Socioecology of the School

	Computation			Concept & Application		
Predictor	Beta	F Value	R Square	Beta	F Value	R Square
Sex	-0.30	9.25*	0.09	-0.29	8.09*	0.08
Ethnicity	0.12	1.13	0.01	0.10	0.74	0.01
Socioecology of School	0.40	12.804*	0.16	0.29	8.09*	0.08

*Significant at .01

Both sex and the socioeconomic context of the school were also non-significant predictors. Similar arguments can also be posited for these variables. The only significant predictor was ethnicity. Computer assisted instruction under this drill and practice program was more effective in raising the learning gains of bicultural than monocultural students.

While there have been few studies comparing the impact of computer assisted instruction on the learning outcomes for different ethnic groups, extensive analysis of its impact on the bilingual population has been done (Saracho, 1982a and 1982b). These studies have shown that CAI tended to have a positive effect on learning for these students. Within the context of this study the differential impact of CAI on the learning gains of monocultural and bilingual high school students however may be partially explained by a factor which may be called computer familiarity.

Table XIV

Regression Results with Dependent Variable, Learning Gains on the Computer and Predictor Variables, Prior Computational Skill Achievement, Previous Achievement in Concept and Application, Sex, Ethnicity and the Socioeconomic Context of the School

Predictors	Beta	F Value	R Square
Prior Computational Achievement	0.18	1.438	0.03
Previous Achievement in Concept & Application	-0.11	0.768	0.01
Sex	0.14	1.639	0.02
Ethnicity	0.24	3.984*	0.06
Socio-economic context of School	-0.15	1.438	0.02

* Significant at .05

Computer assisted instruction in this school district was implemented as an aide for the bilingual student population. These students, therefore, have spent longer hours and consequently have developed a greater degree of familiarity with the computer than monolingual students. As a novel form of instructional strategy, one can expect that there is a period of adjustment to the computer. While other course packages allow for this period of adjustment, the Adult Arithmatic Skill course, does not; therefore, differences which we are finding between the ethnic groups may be reflecting factors related to student adjustment to the computer.

The accumulated impact of these pre-entry variables on students' mathematics gain is relatively marginal, with these variables accounting for 14 percent of the variance in mathematics achievement. These findings underscore some of the theoretical work that has been done on mastery learning. (See Bloom, 1983, Carroll, 1963). (Individualized Computer programs are structured around a mastery concept of learning). Carroll (1963) has posited that learners will succeed in mastering a given task to the extent that they received quality instruction and that they spend the amount of time on the task that they individually need to learn it. Thus, initial differences among learners will not be reflected in final differences in achievement, though the time that students need for mastery will vary.

D. STUDENTS' PERFORMANCE ON THE MATHEMATICS CONTENT STRANDS

The previous analysis focussed on students' overall academic performance in mathematics on the computer, without looking at differences in mastery levels for the various mathematical tasks. Mathematics achievement is, however, not a unitary phenomenon. The available body of research indicates quite strongly that achievement in mathematics is largely dependent on the nature of the mathematical task. Further, various types of cognitive models can be used to explain the development of various mathematical skills.

Many low level skills in arithmetic (for example, simple addition, subtraction and multiplication) can best be explained in terms of mechanistic models, while more complex arithmetic and problem solving skills lend themselves to an organismic analysis (Carpenter, 1980). The difference between both types of models pivots around the complexity of the cognitive processes involved. Given the nature of the drill and practice format of the adult arithmetic skills course, one can hypothesize that improvement in mathematics competency for the lower level computational skills is likely to occur at a greater rate than the more complex computational skills.

With this hypothesis as a conceptual guiding point, three lines of inquiry pertaining to the impact of computer assisted instruction on the development of proficiency in simple and complex computational skills were initiated. First, we attempted to estimate the degree of skill deficiency that learners were experiencing on entering the program by comparing their pretest means for each mathematic skill. Second, the relative impact of computer assisted instruction on each skill area was arrived at by

comparing the relative learning gains demonstrated by students in these areas. Third, the extent to which CAI helped particular learners in the development of simple and complex mathematical skills was determined by looking at the Spearman rank correlations between mastery of simple and complex computational skills and various learner's characteristics.

Table XV presents information pertinent to answering the first question. Observations of the pretest means indicate not surprisingly that students are experiencing the greatest difficulties in mastering the more complex computational skills. Indeed, the pattern evident in the table is for mastery to decline as the skill becomes more complex. (Although the pretest mean for the measurement skill was relatively high, only a few students had reached a level of mastery in the other skill areas to be eligible to receive problems on this strand).

Comparison of the postest means with the pretest means and the Wilcoxon z values reported indicate that students have made significant positive learning gains in all of the 7 mathematical content areas.

Table XV
Pretest and Posttest Means, Standard Deviations
and Wilcoxon z Values for the Mathematic Content Strands

Content Strand	Mean	Standard Deviation	Mean	Standard Deviation	Change	Wilcoxon z Value
Addition	66.405	21.851	84.372	22.576	18.967	6.494*
Subtraction	59.044	17.460	72.087	21.466	13.043	6.698*
Multiplication	57.593	18.513	69.100	21.914	11.507	5.991*
Division	57.048	16.438	63.875	18.541	6.827	4.456*
Equation	47.840	8.936	52.757	15.626	4.917	4.258*
Fraction	54.273	6.526	58.778	14.513	4.505	3.351*
Measurement	73.682	12.167	76.143	17.490	2.461	2.187**

*Significant at .01
**Significant at .05

However, although CAI has had a facilitating effect in minimizing mathematical deficiencies on each of the content strands, the rate of mastery differs. It is obvious from the table that the more immediate impact of the program is on the lower computational skills. Thus, students have made the clearest gains in addition and subtraction and multiplication. The rate of progress is, however, slowed for the more complex computational strands, for example, equations, fractions and measurement.

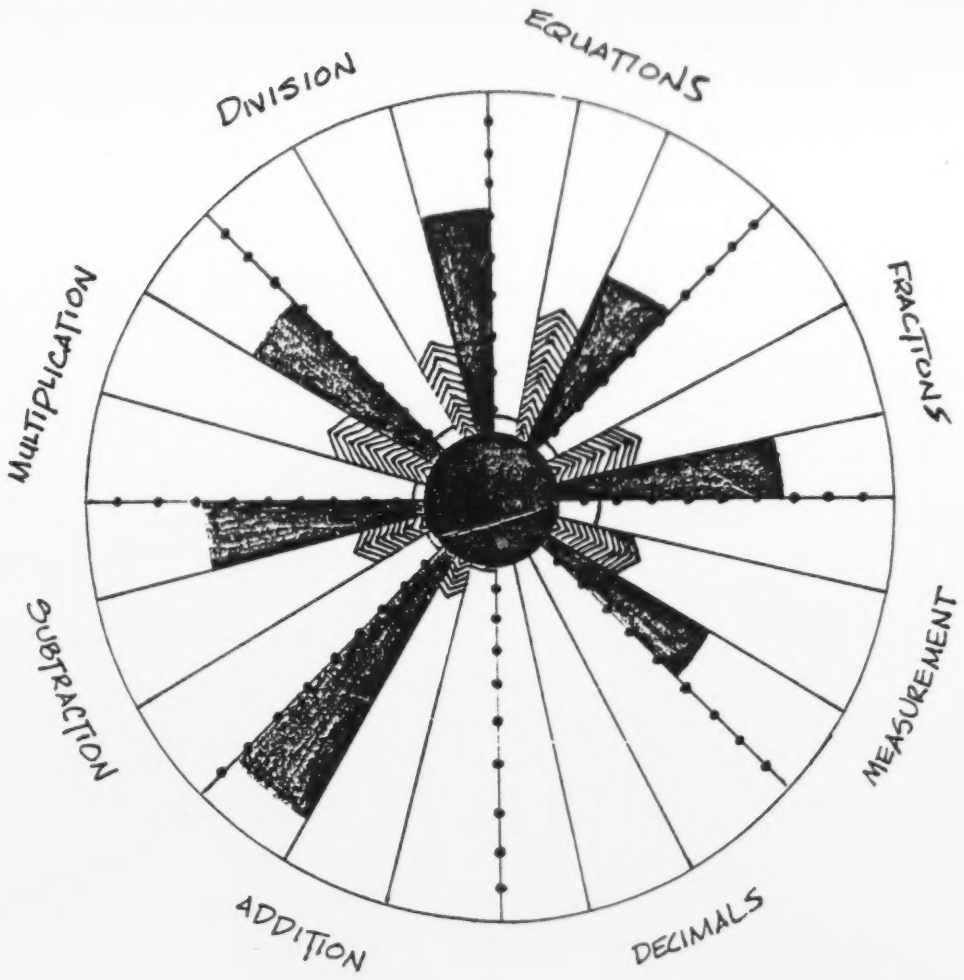
An alternative presentation of this information can be found in the chart on page 47. The chart provides three pieces of information for each of the skill areas. First, it gives the percentage of students who were able to increase their mastery of the more difficult items over the pretest. The second percentage given is the number of students who are working on problems at the same level of difficulty and the third set of information pertains to the percentage of students whose mastery levels have actually fallen below their starting level in the program.

As is evident from Figure 2, the skill areas of measurement and equations are the most problematic. For equations, only 52 percent of the students were able to increase their mastery of the more difficult items for this skill, 40 percent remained at the same level of difficulty and 8 percent declined. On the measurement strand, while 57 percent improved their mastery levels, 29 percent remained at the same difficulty level and 14 percent declined.

Figure 2

PIE CHART OF STUDENT PROGRESS ON EACH

OF THE MATHEMATICS STRANDS



Increased Mastery

Remained at Same Level of Mastery

Decreased Mastery Level

Represents Ten Percent (10%)

The percentages reported for students who have increased their mastery or who have remained at the same levels in these skill areas underscore the general conclusion that longer time is needed to master these more difficult skills. However, the information presented on those who have actually fallen below their initial level is of some concern. This suggests that students were either started at too high a level on this skill, or alternatively, that the basic mathematical algorithms for this skill are not being learned, hence, students are experiencing difficulties in transfering their knowledge on the simple items to solving more complex tasks.

For those students who are missing all items at a particular level, project teachers may want to initiate fixed drills on these skills, so as to give these students sufficient practice in these areas. Further, the information presented in Table XV and Figure 2 may be quite useful to those project teachers who have students in CAI. For one, the fairly strong impact of CAI on simple computational skills suggests that project teachers may want to devote proportionately more time to teaching the more complex skills such as equations, fractions and measurement which are not as easily malleable to change. Alternate instructional strategies such as workbook activities may also be useful in supplementing computer instruction in these skill areas.

Since we know that the computer is having a differential impact on improving skill competency for the simple and more complex computational skills, of interest was seeing which students the computer was helping in which sets of skills. For the purpose of this analysis, a dichotomy was employed, where addition, subtraction and multiplication were combined and taken to represent lower mathematical skills, and equations, fractions and

measurement were grouped as representing more complex arithmetic skills. A series of Spearman rank correlation coefficients (rho) were computed in order to see the relationship between the development of skill competency for the simpler and more difficult tasks and certain student characteristics.

The correlation coeficients reported in Table XVI reflect a number of interesting relationships. Firstly, the correlation between mastery of simple and mastery of more advanced computational skills implies that

Table XVI

Spearman Rank Correlation Coefficients Representing Relationships Between Mastery of Simple and Difficult Computational Skills and Selected Student Characteristics

	X1	X2	X3	X4	X5	X6	X7
Mastery of Simple Computation Skills (X1)	1.00						
Mastery of Advanced Computational Skills (X2	0.67**	1.00					
Sex (X3	0.09	-0.32	1.00				
Ethnicity (X4)	0.27*	0.66*	-0.28	1.00			
Achievement on CTBS Concept & Application (X5)	0.01	-0.43**	0.31	0.03	1.00		
Achievement on CTBS Computation (X6)	-0.03	0.06	0.26	0.03	0.61*	1.00	
Socioeconomic Characteristic of School (X7)	-0.32*	0.81*	0.13	-0.56*	0.18	0.27*	1.00

*Statistically Significant at .01
**Statistically Significant at .05

students who are successfully mastering the simple computational skills are also doing well on the more complex tasks. However, the less than perfect correlation suggests that acquisition of simple computational skills, though necessary prerequisites, are not the only skills necessary for successfully mastering the more difficult skills.

Bicultural students appear to have been helped significantly on both sets of skills, though the strength of the relationship suggests a stronger relationship with the more complex skills. This finding certainly serves to substantiate the thesis that the more difficult skills require a longer period of time for mastery, since, as was previously cited, these students have spent a longer time on the computer than monolingual students.

While computer assisted instruction is helping all ability range students (as measured by past performance on the CTBS concepts and application and computation) in the development of addition, subtraction, and multiplication competencies, on the more advanced arithmetic skills (fractions, measurement and equations) the lower ability students are being helped more ($r=-.43$).

E. THE IMPACT OF TIME ON TASK AND INSTRUCTIONAL MANAGEMENT ON ACHIEVEMENT

Two critical instructional factors that have been found to be highly correlated with achievement are "teacher competency" and "student engaged time". It is instructive to note that the research on learning outcomes has shown that the impact of any instructional program or innovation on pupil achievement can be stymied or enhanced by the quality of the instructional management (Mitzel, 1960; Medley, 1982). Indeed the results of several process - product studies have schematically presented learning outcomes to be influenced by teacher competency, teacher performance, and pupil learning experiences (Mitzel, 1960; Medley, 1975).

The second important variable, "student-engaged time", concerns the extent to which students are actively involved in learning. The substantive findings in the literature underscores the saliency of time on task as a discriminating factor in explaining achievement.

The extent to which these two factors had explanatory significance in accounting for the differences in mathematics achievement in this sample was explored. In our sample of students thirty five were receiving computer assisted instruction supervised by a teacher's aide while sixty one were being supervised by a remedial math specialist. Whether this factor, as well as the time spent on task, made a difference in the learning gains students derived from computer assisted instruction was determined by the use of linear flow graphs. This technique is extremely useful for understanding the relationship between categorical variables, particularly when one is interested in decomposing inferred change in a dependent variable (Davis, 1976).

For the purpose of this analysis, student mathematics achievement was dichotomized into high and low. This dichotomization was based on whether students had increased the levels of difficulty for their course average by 4. Since there are 36 levels of difficulty on the Adult Arithmetic course, it was estimated that a change of 4 would represent a month's gain. Thus, students who had changes of less than 4 were classified as low achievers, and those with a month or more gain were classified as high achievers. Similar techniques were used for the time on task variable. This variable was dichotomized as low time on task or high time on task through the use of a median split. Students who spent less than 148 minutes on the terminal were classified as having low time on task, and conversely those who had spent 148 minutes or more were classified as having high time on task.

The relationship between the instructional management of the program and achievement can be gleaned from Table XVII and Figure 3. The conditional proportions in the table reflect that proportionately more students being supervised by trained teachers have experienced high achievement (.475) than those being supervised by an aide (.114). The difference between the two proportions is .36 in favor of project teachers. One may interpret this difference as implying that if one were to shift from having the program being supervised by an aide to a project teacher that one would increase the number of students having high achievement gains by 36 percent. (This relationship is graphed in Figure 3)

Table XVII

Relationship Between Instructional Management and Mathematic Achievement

Instructional Manager	Achievement		
	Low Achievement	High Achievement	
Project Teacher	32	(.475) 29	61 (.635)
Teacher Aide	31	(.114) 4	35 (.364)
Totals	63	33	96

a=.36

High Achievement=(.360 x .635 + .114 = .34

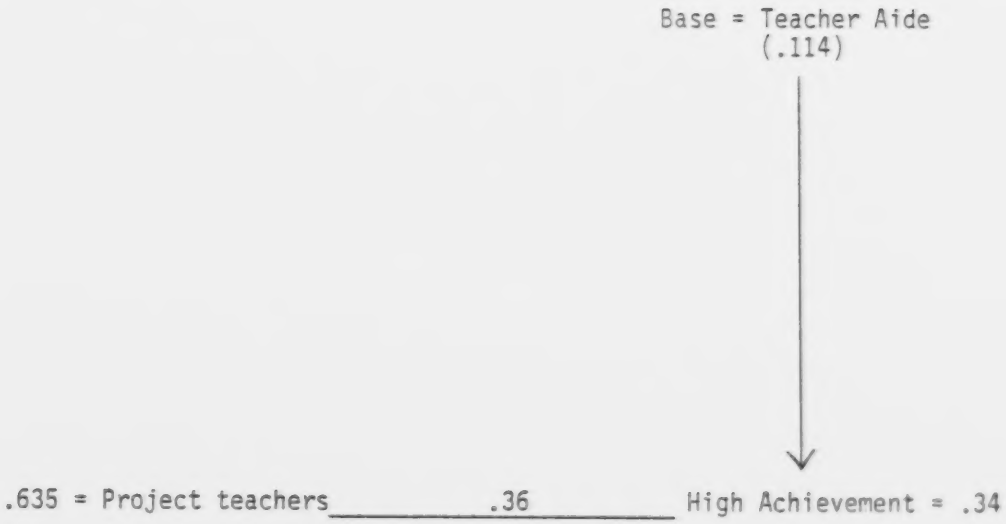


Figure 3: Flow Graph of Relationship Between Instructional Management and High Mathematic Achievement

The association between time on task and mathematics achievement is illuminated in Tables XVIII and Figure 4. As is starkly evident from the table, learning gains on the computer are closely related to time on task. Approximately half the students with high time on task experienced a month or more learning gain (.527). If one takes the difference between this proportion (.527) and the proportion of those students with low time on task and similar learning gains (.0974) one gets a value of .429. This may be interpreted as meaning that by simply increasing students time on task from less than 148 minutes to more than 148 minutes or from low to high, one would increase the proportion of students with high learning gains by 43 percent.

Table XVIII

The Relationship Between Time on Task
and Mathematics Achievement

Time on Task	Achievement		
	Low Achievement	High Achievement	
High time on task	26	(.527) 29	55 (.573)
Low time on task	37	(.097) 4	41 (.427)
Totals	63	33	96

a=.429
High Achievement=(.429 x .573 + .097 = .34

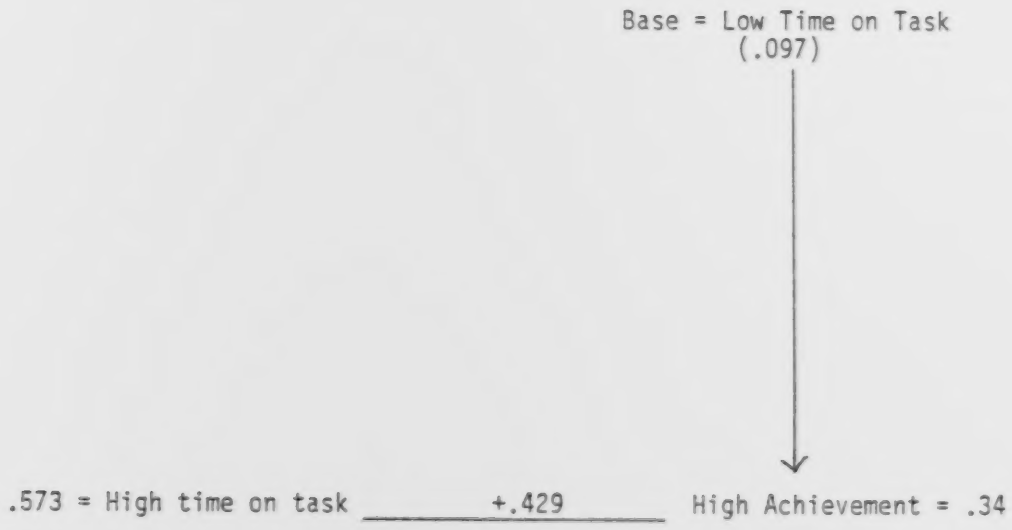


Figure 4: Flow Graph of Relationship Between Time
on Task and High Mathematics Achievement

A comparison of the relative weights associated with the d values for time on task and instructional management suggests that of the two instructional variables, time on task has the most important impact on mathematics achievement.

Discussion

The preceeding analyses of high school students' achievement on the computer have afforded us some insight into the factors that are related to mathematics achievement on the computer. A number of implications loom large.

First, the findings which have clustered around the neglible effects of previous academic as well other non-instructional differences (eg sex) on learning outcomes in the CAI program highlight the importance of the mastery concept of learning especially with remedial populations. It is patently clear that when instruction is tailored to meet the individual student's need, and when there is consistency in the quality of the instruction to which all learners are exposed, differences due to noninstructional factors between learners are, if not totally obviated, at least minimized.

Second, the information generated by this study on the mathematics content strands points us in some useful directions in terms of the alignment of the instructional activities within the classroom and instruction on the computer. The richness of the information provided by the computer on the content strands can be used by remedial math teachers for both diagnostic as well as teaching purposes. Further, the differential impact of the computer in remediating dificiencies for simple as well as more difficult mathematical skills suggests that one way of maximizing the benifits that students receive from remediation is to

allocate the remediation of simple computational skills to the computer, while project teachers focus their efforts on dealing with the more complex mathematical skills.

Third, the impact of instructional management on student achievement in the program is highly suggestive of the need for there to be continuity in the instructional interaction between teachers and students while students are on the computer. Although the computer provides immediate feedback, the quality of that feedback is extremely limited. Students are not told why they are getting a problem incorrect by the computer. This has serious implications when one starts to address the issue of retention effects of computer assisted instruction - a question which appears to have no definitive answers when one review the studies that have been done on this topic. In fact Kulik (1983) has noted in a review of five studies on this issue that the retention effects of CAI were not statistically significant, and in one case were higher for students not in the CAI program.

RECOMMENDATIONS

Based on the foregoing analysis of Computer Assisted Instruction, we offer the following recommendations:

1. The coordination of instruction between the classroom and the computer program should be improved. Students would benefit if their strengths and weaknesses were dealt with in both places in a concerted effort.

2. Given that some skills are considered by Newark students to be more difficult than others, more time - more computer time and more classroom time - should be spent on these skills. Specifically, the more difficult skills are equations, measurement, fractions and decimals.

3. Second graders as a group seem to be too young to benefit greatly from CAI instruction, and higher ability third graders benefit more than lower ability ones. This suggests that second graders and lower ability third graders should probably not be instructed in math through CAI.

4. Whatever differences in performance that were found at the upper elementary and high school levels were in favor of lower ability students; thus, CAI seems to be a good remedial tool.

5. Teachers should supervise students on CAI. The computer does not tell a student why a mistake was made. Students benefit more when there is a dialogue between teachers and students.

6. Although boys did do better in problem solving skills (used only by upper elementary students), girls did as well as, if not better than boys in all other skills. Computers do not differentiate between sexes. This should be a lesson for teachers and for girls, themselves. Math proficiency is probably not biologically predetermined.

REFERENCES

Aiken, L. R. "Intellective Variables and Mathematic Achievement. Directions for Research." Journal Social Psychology 1971, 9: 201-212.

Bloom, B. S. All Our Children Learning. New York: Mcgraw- Hill, 1981.

Bloom, B. S. "Mastery Learning." Evaluation Comment. 1, 2. 1968.

Bruner, J. The Process of Education. New York: Random House, 1960.

Burns, P. K. and Bozeman, W. C. "Computer Assisted Instruction and Mathematic Achievement: Is There a Relationship." Educational Technology 1981, 21, 32-39.

Callahan, L. C. and Glennon, V. J. Elementary School Mathematics: A Guide to Current Research (4th Ed.). Washington, D.C. Association For Supervision and Curriculum Development, 1975.

Carpenter, T. P. "Research in Cognitive Development." In R. Shumway (ed.). Research in Mathematics Education. Reston V. A. National Council of Teachers of Mathematics: 1980.

Carroll, J. "A Model of School Learning." Teaching College Record 1963, 64, 723-33.

Coleman, J. S., Campbell, E. G. et al. Equality of Education Opportunity. Washington, D.C., U.S. Government Printing Office, 1966.

Cranford, H. R. A. A Study of the Effects of Computer-Assisted Instruction in Mathematics on the Achievement and Attitudes of Pupils in Grades Five and Six in a Rural Setting. Doctoral Dissertation. University of Southern Mississippi: 1976. D.A.I. 1976, 37A, 5660.

Davis, J. A. "Analyzing Contingency Tables with Linear Flow Graphs: D Systems." In D. R. Heise (ed) Sociological Methodology. pp. 111-145. Jossey-Bass: San Fransisco, 1976.

Eschenburg, W. F. Computerized Prescription Mathematics in Support of Group Instruction. Doctoral Dissertation. Wayne State University, 1976. D.A.I. 1976, 37A, 7007.

Fenneman, E. and Sherman, J. "Sex related Differences in Mathematics Achievement, Spatical Visualization and Affective Factors." American Educational Research Journal. 14:51-71.

Fenneman, E. "Sex Differences in Mathematics Achievement: A Review." Journal for Research in Mathematics Education, 1974, 5:126-139.

Gibb, E. A. and Lamb, Charles E. "Arithmetic Skills." Encyclopedia of Educational Research, 1982: 148-155.

Glass, G. V. "Primary, Secondary, and Meta - Analysis of Research." Educational Research, 1976, 5, 3-8.

Hall, K. A. "Computer - Based Education." Encyclopedia of Educational Research, 1982: 360-363.

Hartley, S. S. "Meta Analysis of the Effects of Individual Paced Instruction in Mathematics." Doctoral Dissertation University of Colorado, 1978.

Kogelman, S. and Warren, J. Mind Over Math. New York: McGraw-Hill, 1979.

Kulik, J. A. et al. "Effects of Computer Based Teaching on Secondary Students." Journal of Educational Psychology. 1983, 75, 19-26.

Lysiak, F. et-al. Computer Assisted Instruction 1975-1976 Report: A Title I Program. Fort Work Texas: For Worth School District, Department of Research and Evaluation: 1976.

Madhere, S. and Walker, E. "Student's Affective Behaviors: Their Social and Personal Correlates and Their Impact on Achievement." Division of Research, Evaluation and Testing: Newark, Board of Education, 1983.

Medley, D. M. "Teachers Job Satisfaction." In Encyclopedia of Educational Research" 1982.

Mitzel, H. E. "Teacher Effectiveness." In C. W. Harris (ed) Encyclopedia of Educational Research. New York: MacMillan, 1960.

Modiseh, D. M. Effects of Computer-Assisted Instruction on Achievement in Remedial Secondary Mathematical Computation. Doctoral Dissertation. Fordham University, 1980. D.A.I. 1980, 11A, 5770.

Mathematical Knowledge and Skills: Selected Results from the Second Assessment of Mathematics. National Assessment of Educational Progress, 1979.

Overton, V. "Research in Instruction Computing and Mathematics." Viewpoints in Teach and Learn, 1981, 52, 2, 23-26.

Pachter, S. N. A. A Computer Assisted Tutorial Module for the Teaching of Factoring of Second Degree Polynomials to Regents Level Ninth Year Mathematics Students. Doctoral Dissertation. Columbia University Teachers College, 1979. D. A. I. 1979, 4A, 1843.

Piaget, J. The Child's Conception of Number. New York: Humanities Press, 1952.

Romero, S. R. The Effectiveness of Computer Assisted Instruction in Mathematics at the Middle School. Doctoral Dissertation. University of the Pacific, 1979. D. A. I. 1979, 2A, 577.

Rosenshine, B. and Furst, J. "Current and Future Research on Teacher Performance Criteria." In B. W. Smith (ed) Research on Teacher Education: A Symposium. Englewood Cliffs, N.J.: Prentice Hall, 1971.

Saracho, O. N. "The Effects of a Computer Assisted Program on Basic Skills Achievement and Attitude Toward Instruction of Spanish Speaking Migrant Children." American Educational Research Journal, 1982, 19, 201-219.

Saracho, O. N. "Planning Computer Assisted Instruction for Spanish-Speaking Migrant Students." Educational Technology System, 1982b, 10:3, 257-260.

Skinner, B. F. The Technology of Teaching. New York: Appleton-Century Crofts, 1968.

Tobias, S. Overcoming Math Anxiety. New York: W. W. Norton, 1978.